Phantom Validation of a Point-Set Deformable Registration Method using Pig Bladder

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Introduction

Deformable image registration (DIR) is widely used for registering medical images. While the main goal of registering images is to correspond different regions of interest (ROI) within the body, surrounding objects and image artefacts can confuse the DIR algorithm. This occurs, for example, in image-guided multi-fraction gyneocological brachytherapy treatment, which uses an intracavitary applicator. Therefore, in applications like dose accumulation for these treatments, an alternative approach is to non-rigidly register delineated ROI contours. However, validating the registration outcomes and accordingly choosing a suitable registration algorithm is challenging, especially for highly deformable ROI with no discriminating features or anatomical landmarks. In this work, a point-set deformable registration technique, called coherent point drift (CPD), is evaluated for registering the bladder surface across treatment fractions.

Methods

A house-made pelvis phantom was used with a freshly harvested pig bladder to model the human anatomy. Multiple plastic and rubber fiducial markers were glued onto the bladder surface at twelve different locations. The bladder was filled with varying amounts (90cc, 180cc, 360cc, and 480 cc) of a water-contrast mixture and CT-scanned each time. The variously filled bladder was contoured manually on each scan using the MIM Maestro software (MIM Software Inc.). In addition, the fiducials were identified on each scan and their positions recorded. The CPD toolbox for MATLAB (Mathworks Inc.) was used to register the contour point-sets of the three smaller bladder sizes to the largest size. The toolbox takes the *target* and *moving* structure coordinates and outputs the *deformed* moving structure coordinates. The fiducial positions were used as landmarks to calculate the target registration errors (TRE) for different points on the bladder surface. Optimized input parameters for CPD registration were found experimentally by searching over the parameter space for values which minimized average TRE over all landmarks.

Results

The appearance of the phantom and the fiducial markers in the CT images was very satisfactory (Fig. 1). The average TRE value obtained for the 480cc-bladder as the *target* structure was 6.4±2.3 mm. TRE values were obtained for alternate target structures, with the 360cc-bladder yielding the lowest TRE value of 5.5±2.1 mm when selected as the target. These TRE values are reasonably small compared to the dimensions of the bladder.

Conclusion

Our validation method shows that the CPD deformable registration technique is a viable method for registering ROI contours, even when lacking distinctive features in the structure.

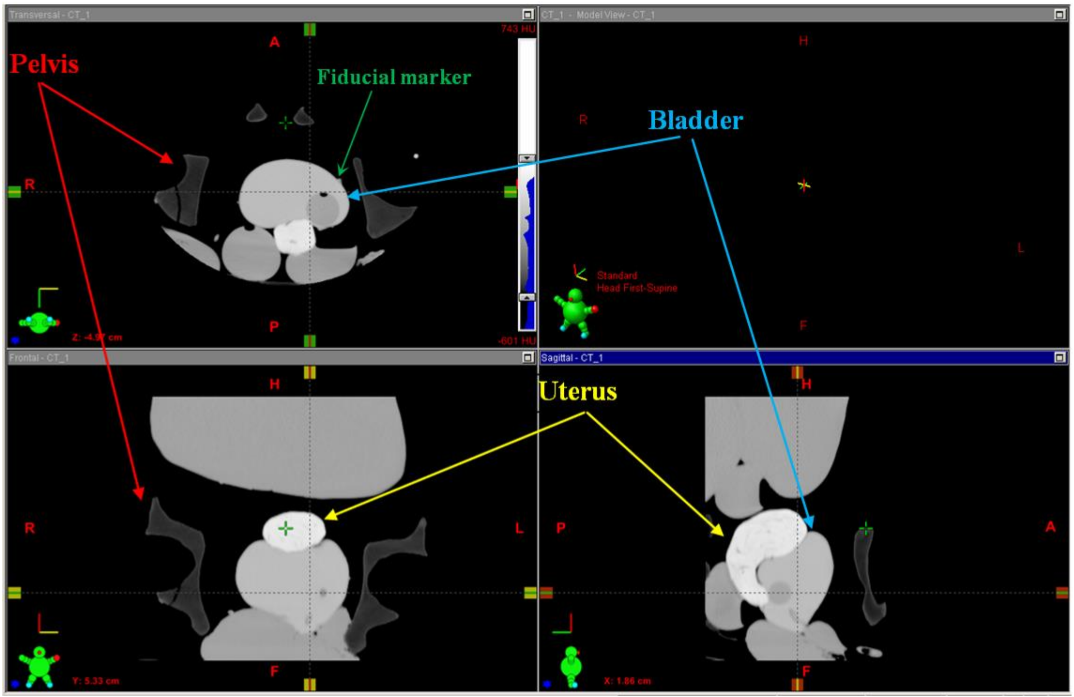

Figure 1. CT scan of the pelvis phantom. The pig bladder, uterus, pelvis bone model and a fiducial marker are labelled. The remaining structures are water-filled bags.